Evaluation of the effectiveness of conventional insecticides against the cowpea weevil, *Callosobruchus maculatus* (Coleoptera: Bruchidae), on four different substrate surfaces

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Abstract: In pest management programs, the control of pests in structural facilities or sites, where processed food products are consumed or stored, requires the application of insecticides upon a variety of substrate surfaces. In order to determine the insecticidal effectiveness on different substrate surfaces, adults of the cowpea weevil, *Callosobruchus maculatus* (F.), were exposed to field recommended concentrations of chlorpyrifos, abamectin and deltamethrin insecticides. The results showed that abamectin caused mortality rates of 63.33%, 22.41%, 12.9% and 11.9% while deltamethrin caused mortality rates of 55%, 44.2%, 41.3% and 37.4% on glass, ceramic tile, plastic and paper disc surfaces, respectively. Exposures to chlorpyrifos led to 100% mortality in all surfaces. Probit analysis of data showed that LC_{50} values were 8.66, 13.6, 29.16 and 56.5 μg/mL for chlorpyrifos, 119.4, 446.2, 774.2 and 836.4 μg/mL for abamectin, and 1 008, 1 131, 1 210 and 1 336 μg/mL for deltamethrin on the glass, ceramic tile, plastic and paper disc surfaces, respectively, based on formulated materials. It is concluded that chlorpyrifos is the most toxic insecticide to the cowpea weevil, but that its toxicity was reduced in the glass, ceramic tile, plastic and paper disc surfaces in sequence.

Key words: *Callosobruchus maculatus*; lethal effects; abamectin; deltamethrin; chlorpyrifos

1 INTRODUCTION

After grain, cereal with 20%-30% protein is considered to be the second major source of food that is attacked during storage by different insects (Koochaki and Banayan-Aval, 1993). The cowpea beetle, *Callosobruchus maculatus* (F.), is one of the most important polyphagous storage pests (Beck and Blumer, 2009). It causes damages to different varieties of beans, peas and other crops (Huignard *et al.*, 1985). Bruchid infestation usually affects seed quality and market value. It can reduce cowpea seed viability to 2% after months of storage (Caswell, 1976; Ofuya and Credl, 1995; Tripath *et al.*, 2001). The quantity of cowpea lost annually through destruction by *C. maculatus* is substantial, although no accurate figures are available. Cowpea damage estimates have always been expressed in percentages (Umeozor, 2005). Cowpea is the stored product most susceptible to this beetle and is almost completely destroyed within a short period of infestation in Iran.

The use of chemical insecticides is a common tool used to control storage pests (Fields, 1998). Chemical compounds used around the world to treat stored products include organophosphate insecticides such as chlorpyrifos methyl, malathion, pyperonyl butoxide and pyrethrins (White and Leesch, 1995); pirimiphos methyl, methyl parathion, dichlorvos and diazinon (Fleurat-Lessard *et al.*, 1998); as well as some synthetic pyrethroids (Hutson, 1979; Hargreaves *et al.*, 2000). Arthur (2008) has shown that, when conducting pest control operations in structural facilities or sites containing processed food products, the variety of substrate surfaces presents a challenge to pest management programs. His research evaluated the effects of chlorfenapyr against two species of *Tribolium* on concrete, vinyl tile and plywood surfaces, and showed that the effectiveness of the insecticide varied among the different surfaces. Similar differences in the effects of pesticides between substrate surfaces were found by Chadwick (1985), and Braness and Bennett (1990). Furthermore, Vojoudi *et al.* (2010) showed that chlorpyrifos had the highest efficacies against *Tribolium castaneum* adults when applied to glass and ceramic tile surfaces in comparison to others, but that this may be formula-dependent (Slowinsky and Gojmerac, 1972). Deltamethrin WP was found to be more effective than deltamethrin EC on a variety of surfaces in bioassay with three *Callosobruchus* species (Jain and Yadav, 1989). This research studied the effects of chlorpyrifos,

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abamectin and deltamethrin insecticides on *C. maculatus* adults when applied to glass, ceramic tile, plastic and paper disc surfaces. The aim was to determine which insecticides and which surfaces would produce the best results in controlling *C. maculatus*.

2 MATERIALS AND METHODS

2.1 Biological materials

The cowpea beetle colony used in this study was obtained from Tarbiat Modarres University, Tehran, Iran. During the rearing of the insect, cowpea was used as a food source. In order to prevent any fungi contamination, cowpea seeds were kept in storage at −20℃ for 24 h before offering to the insects. Fifty pairs of *C. maculatus* adults were reared in 1.5 L wide-mouth glass jars containing 200 g seeds of cowpea. The insects were maintained under controlled temperature and humidity of 26 ± 1℃, 65% ±5% RH. To attain young (< 24 h) adults, seeds with pupae window were separated and after one day, emerging adults were collected by an aspirator and used for bioassay tests.

2.2 Insecticides

The insecticides used in the experiments were chlorpyrifos (Dursban® 48EC, DowElanco Co., England), abamectin (Vermitec® 1.8EC, Gyah Co., Iran) and deltamethrin (Decis® 2.5EC, Aria Shimi Co., Iran).

2.3 Bioassays

Appropriate amounts of each insecticide were diluted with 100 mL of distilled water to provide the recommended field concentrations. The concentrations were 720, 25 and 3.6 mg a.i. /L for chlorpyrifos, deltamthrin and abamectin, respectively. Tween 80 was used as a surfactant at concentration of 500 μg/mL in dilutions. The experiments were carried out by using solution spray on the surfaces. Young adults (< 24h) of the *C. maculatus* were exposed to fresh residue of the insecticides in field recommended concentrations of each insecticide on different surfaces for 24 h. After 24 h initial exposure, numbers of dead and live beetles were recorded and subjected to analysis of variance. For lethal concentration bioassays, a stock solution at a volume of mL was prepared for each insecticide. Aliquots were taken from the stock solution and mixed with water to prepare the following concentrations. Petri dishes were treated with 2 mL of each insecticide dilution. Treating the inside surface of dish lids was necessary to ensure exposure of the pesticides to the adult cowpea beetles as they could fly upside on Petri dishes surfaces. The control plates were sprayed with distilled water plus Tween 80. Twenty young adult females (< 24 h) were randomly separated from the culture and introduced into each deposit level. The exposure surfaces were transferred to the growth chamber as per the previously mentioned conditions for 24 h. The numbers of dead and live insects were counted after 24 h after initial exposure to the insecticide residue. The bioassays were replicated three times.

2.4 Data analysis

Trials were tested for lack of fit by using PROC GENMOD procedures and data were analyzed using proc probit procedure (SAS Institute, 2002) to compute lethal concentrations with associated 95% fiducial limits. All data were subjected to ANOVA percentage mortalities. Means were compared using Tukey's test (SPSS, 2004).

3 RESULTS

With regard to the importance of stored products, in this study the effects of chlorpyrifos, abamectin and deltamethrin insecticides were evaluated on glass, ceramic tile, plastic and paper disc surfaces. The results showed that the effect of chlorpyrifos on the four described surfaces vary significantly (Table 1), and the highest mortality occurred on the glass surface.

Abamectin insecticide also showed significant differences related to the variety of surfaces (Table 1), but deltamethrin did not show significant differences between glass, ceramic tile and plastic surfaces nor with the plastic with paper disk surfaces according to overlapping of LC_{50} values of confidence intervals of insecticide on different surfaces (Table 1). Furthermore, the results showed that all surfaces had significantly different effects in different insecticides. The LC_{50} values of each of three insecticides increased on glass, ceramic tile, plastic and paper disc surfaces, respectively (Table 1). Also the percentage mortality of *C. maculatus* that were exposed to the field recommended concentrations of insecticides on different surfaces showed that chlorpyrifos insecticide caused 100% mortality at all surfaces. Both abamectin and deltamethrin achieved increasingly lower percentages of mortality on glass, ceramic tile, plastic and paper disc surfaces in sequence (Fig. 1, Table 2). The results showed that glass surface significantly affected the mortality in insecticide treatments compared to the control ($F = 102.34$; $df = 3, 35$; $P < 0.0001$) (Table 2). Moreover, field recommended concentrations

Table 1 LC_{50} values of chlorpyrifos, abamectin and deltamethrin insecticides on different substrate surfaces on *Callosobruchus maculatus*

Pesticides	Substrates	n	Slope ± *SE*	χ^2	LC_{50} (95% FL) Lethal concentrations (μg/mL) or [μg a. i./mL]
Chlorpyrifos	Glass	420	4.8 ± 0.6	63.57	8.66 (8.06 – 9.34) [4.16]
	Ceramic tile	420	4.9 ± 0.7	55.13	13.60 (12.60 – 14.60) [6.53]
	Plastic	420	3.8 ± 0.5	52.11	29.15 (26.60 – 32.20) [14.00]
	Paper disc	420	9.0 ± 1.2	55.24	56.50 (54.30 – 58.70) [27.12]
Abamectin	Glass	420	2.1 ± 0.3	55.36	119.40 (101.30 – 140.20) [2.15]
	Ceramic tile	420	7.0 ± 1.0	46.11	446.20 (425.06 – 471.10) [8.03]
	Plastic	420	13.1 ± 1.6	64.63	774.24 (753.70 – 796.04) [13.94]
	Paper disc	420	9.0 ± 1.2	56.05	836.40 (804.98 – 872.60) [15.06]
Deltamethrin	Glass	420	6.0 ± 0.8	57.81	1 008 (980 – 1 104) [25.20]
	Ceramic tile	420	7.2 ± 0.9	57.74	1 131 (1 078 – 1 189) [28.28]
	Plastic	420	7.3 ± 1.0	51.60	1 210 (1 155 – 1 275) [30.25]
	Paper disc	420	7.3 ± 1.0	52.85	1 336 (1 275 – 1 403) [33.40]

Lethal concentrations and 95% fiducial limits (FL) were estimated using logistic regression (SAS Institute, 2002).

Table 2 Percentage mortality of *Callosobruchus maculatus* adults on different substrate surfaces treated with insecticides at field recommended concentrations

Treatment	Concentration (μg/mL) or [mg a. i./L]	Substrates			
		Glass	Ceramic tile	Plastic	Paper disc
Chlorpyrifos	1 500 [720]	100 ± 0 a	100 ± 0 a	100 ± 0 a	100 ± 0 a
Deltamethrin	1 000 [25]	55.00 ± 5.3 b	44.20 ± 5.3 b	41.32 ± 5.8 b	37.40 ± 4.6 b
Abamectin	200 [3.6]	63.33 ± 5.8 b	22.41 ± 2.8 c	12.90 ± 4.3 c	11.90 ± 4.5 c
Control (Tween 80)	–	2.22 ± 1.5 c	3.33 ± 1.7 d	0 ± 0 c	1.11 ± 1.1 c

Means in a column followed by different small letters are significantly different (Tukey, $a < 0.05$)

of insecticides on plastic surfaces showed different effects ($F = 152.8$; $df = 3, 35$; $P < 0.0001$).

4 DISCUSSION

In pest management programs, the control of pests in structural facilities or sites where processed food products are consumed or stored, requires the application of insecticides upon a variety of substrate surfaces. During the past 30 – 40 years there have been a number of tests in which stored product insects have been exposed on various treated surfaces such as glass, paper disc, ceramic tile, plastic, fiberboard and others (Arthur, 2008). Williams *et al.* (1983) reported that insecticides have different levels of effectiveness depending on the type of surfaces. The recent results are consistent with our results. LaHue (1977) reported that *Tribolium*

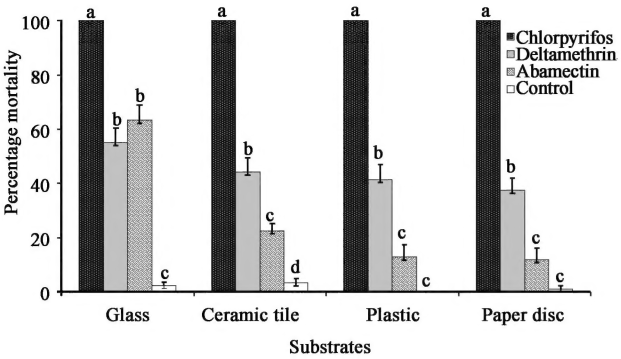

Fig. 1 Mortality of *Callosobruchus maculatus* adults on different substrate surfaces treated with insecticides at field recommended concentrations
Data in the figure are represented as mean ± *SE*.

showed 98% mortality after 12 months. Arthur (1996) reported that *T. castaneum* and *Rhyzopertha dominica* were controlled by deltamethrin dust but that there were no significant differences among the three surfaces or between the two methods of exposure. Arthur (2008) reported that exposure to chlorfenapyr is effective against *T. castaneum* and *T. confusum*, but efficacy will vary depending on the surface substrate.

The results showed that the susceptibility of *C. maculatus* on glass, ceramic tile, plastic and paper disc surfaces to the all insecticides will be reduced, respectively while chlorpyrifos was the most toxic compound to this pest on glass surfaces. Chlorpyrifos on paper disc surface had the lowest toxicity to *C. maculatus* adults due to high porosity. Finally, it was determined that chlorpyrifos on glass surfaces had the highest effectiveness in controlling *C. maculatus*.

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四种基质表面上常规杀虫剂对四纹豆象的药效评价

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摘要：在害虫治理中，在消费或贮藏粮食加工产品的建筑设施或场所进行害虫防治需要将杀虫剂施用在各种基质表面上。为了测定不同基质表面上杀虫剂的药效，将四纹豆象 *Callosobruchus maculatus*（F.）成虫接触田间推荐剂量的阿维菌素、溴氰菊酯和毒死蜱。结果表明：施用在玻璃、瓷砖、塑料和纸盘表面上，阿维菌素对四纹豆象成虫的致死率分别为 63.33%，22.41%，12.9% 和 11.9%，而溴氰菊酯在这 4 种基质表面上对四纹豆象成虫的致死率分别为 55%，44.2%，41.3% 和 37.4%。在所有基质表面上接触毒死蜱，四纹豆象成虫的死亡率均为 100%。对数据进行的 Probit 分析表明，毒死蜱制剂在玻璃、瓷砖、塑料和纸盘上对四纹豆象成虫 的 LC_{50} 值分别为 8.66，13.6，29.16 和 56.5 μg/mL，阿维菌素制剂的相应数值分别为 119.4，446.2，774.2 和 836.4 μg/mL，溴氰菊酯制剂的相应数值分别为 1 008，1 131，1 210 和 1 336 μg/mL。据此推断，毒死蜱对四纹豆象的毒性最强，且在玻璃、瓷砖、塑料和纸盘表面上的毒性依次降低。

关键词：四纹豆象；致死效应；阿维菌素；溴氰菊酯；毒死蜱

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